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Article

The Anatomy of Unaffordable Electricity in Northern Europe in 2021

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Abstract: European electricity prices soared to unusually high levels during 2021, which exposed vulnerabilities in the economy and led to concerns about affordability. The concerns were further exacerbated in 2022, as Europe strove to cut its dependence on the Russian fossil fuel supply, as a result of the Russian invasion of Ukraine. This article explores the causes of the price increases in 2021 and assesses their likely future development by using Finland as a case example. We address a gap in the existing energy literature by elucidating the origins and future outlooks of price spikes in highly interconnected electricity markets. Based on an interdisciplinary combination of legal and qualitative data analysis, this study approaches its key objective in three stages. First, we describe the European market and its regulatory design to demonstrate the legislative framework and preconditions within which the market is expected to operate and how these rules connect to guaranteeing the affordability of electricity. Second, we explore how these preconditions functioned in practice in 2021 by analysing the wider macro-level trends that resulted in the elevated prices throughout Europe, particularly in Finland. Third, we assess the impacts of these trends on Finnish electricity price development. Based on these descriptive and predictive analyses, we show that the European market design fundamentally necessitates price variation to ensure market-based investment and energy security in the long-term. Our analysis demonstrates that the high energy prices in 2021 were, in general, the result of various weather-related, economic, and political factors. Moreover, our findings indicate that the dynamics of price formation within a Member State are complex, and in the case of Finland, strongly impacted by neighbouring markets.

Keywords: energy market analysis; energy security; energy policy; affordability; price peaks

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1. Introduction

1.1. Research Objectives

The year 2021 witnessed the compounding of multiple interlinked phenomena resulting in record-high electricity wholesale prices throughout Europe. In comparison with the unusually low electricity prices in 2020, this increase in price was drastic: the average day-ahead prices increased +218% in Germany, +239% in France, and +470% in the Nordic countries [1]. An increase of this magnitude led to bankruptcies [2,3], amplified inflation [4], and raised deep concern about the affordability of electricity, particularly for energy-intensive and cold countries such as Finland [5]. This trend has continued in 2022 as Europe now strives to cut its dependence on Russian fossil fuel imports, leading to even higher energy prices, most likely to continue into spring 2023. It is in this context that we examine the anatomy of high energy prices in Northern Europe, using Finland as an illustrative case-example of the dynamics of these price developments.

From the perspective of the European electricity market, price variations with sometimes even extremely high electricity prices are not necessarily unwelcome. In fact, regulatory intervention to cap wholesale electricity prices, even when dramatically high, is generally prohibited by EU law (Article 10 of the Electricity Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, OJ L 158, 14.6.2019, p. 54–124). The European electricity market is built on the assumption that a competitive single market, where electricity flows freely across borders and prices are formed based on supply and demand, is the most efficient means of ensuring the availability of sustainable and affordable electricity to all Europeans [6]. This market design also means that prices must be allowed to rise to a level that signals scarcity, leading to market-based investment [7].

However, extreme price increases also raise legitimate concerns over energy security and affordability as an element of energy security [8]. To address these concerns, the European legislation has adopted a framework for protecting vulnerable consumers and mitigating energy poverty [9], and is likely to develop more such instruments to mitigate the price effects from phasing out Russian fossil fuel supplies [10]. Nevertheless, allowing high market-based prices and safeguarding affordability is a delicate balancing act in the EU market design. The exceptionally high end-consumer energy prices have also led to most EU countries setting up support mechanisms for vulnerable households [11]. The Swedish government decided in January 2022 to provide a maximum of 6000 SEK (about 580 EUR) in support for about 1.8 million Swedish households [12], and Estonia has implemented discounted electricity prices for low-income households, as well as reduced network fees for all consumers [13]. Until very recently, Finland was one of the few EU countries that had not initiated mechanisms to compensate the sudden high energy prices for consumers [14].

The objective of this article is to explain and explore the causes of the radical price increases in 2021 and to assess likely future developments. Although there has been research done, inter alia, on the impact of renewable energy sources on electricity price formation [15], the growing role of natural gas in setting the European price levels [16], electricity price forecasting with different mathematical methodologies [17], and the long-term market values of renewable generation [18], the detailed origins and future outlook of sharp price peaks in highly interconnected electricity markets remain poorly understood. From a legal point of view, the European energy market design and its general approach to price formation have been described in EU legal scholarship, but these contributions lack an interdisciplinary and country-specific analysis of how the legal framework functions in practice [19,20]. This article aims to fill these research gaps by using Finland as a case study to demonstrate the functioning of the legal framework in practice and the complex nature of price formation in the European electricity market. To explore the practical reasons for electricity price peaks in highly interconnected markets, the paper focuses on the more detailed market dynamics during the price peaks in December 2021.

Finland offers an illustrative case study of the complexity between market-based price formation and safeguarding affordability. This is due to its cold climate, energy-intensive industry, and geographical location between the Baltics and the other Nordic countries; the Baltic states suffer from energy poverty and energy dependence, whereas Finland's neighbours to the west, Sweden and Norway, are known for their abundant hydro resources and corresponding flexibility, as well as relatively low emissions and price levels [21]. Moreover, Finland shares over 1000 kilometres of border with Russia, from which Finland has historically imported the majority of its fossil fuels and a notable amount of electricity, albeit the electricity imports from Russia ceased in May 2022 [22]. The next subsection describes the data and methods used in this study.

1.2. Data and Methods

We approach our key objective in three stages. First, we describe the European market and its regulatory design to demonstrate the legislative framework, the preconditions within which the market is expected to operate, and how these rules connect to guaranteeing the affordability of electricity (Section 2). This stage is based on a doctrinal legal analysis of the relevant legal framework in the EU and produces a descriptive analysis of the regulatory preconditions under which the European electricity markets are expected to function.

Second, we explore how these preconditions functioned in practice in 2021 by analysing the wider macro-level trends that resulted in the elevated prices throughout Europe, and particularly, in Finland (Section 3). This stage is based on qualitative data analysis, for which the main data sources were the European Network of Transmission System Operators for Electricity (ENTSO-E) Transparency Platform [21] for hourly fundamental power system generation and transmission data and annual installed capacities, Nord Pool [1] for physical electricity day-ahead and intraday market prices and supply and bid curves, Ember for historical CO_2 [23], MarketWatch for coal price data [24], Yahoo Finance [25] for gas price data, Platts [26] for technical properties, to calculate the generation costs for different production types, and Finnish Energy [27] for details on Finnish capacity and generation. Moreover, the analysis included weather-related data, reports on energy imports and exports, and power plant data from plant owner websites and reports.

Third, because the primary energy supply in Europe and in Finland are likely to undergo a massive transformation by winter 2022–2023, the article briefly assesses the impacts of these fundamental changes on Finnish electricity price development through the findings from Section 3 (Section 4). This stage is also based on qualitative data analysis. In addition to the data sources used in stage two, this stage also analyses financial market data from Intercontinental Exchange (ICE) [28], Nasdaq [29], etc. Finally, the article offers conclusions based on these descriptive and predictive analyses (Section 5).

2. The European Market and Regulatory Design

The EU's internal market in electricity is based on the idea of pooling the resources of all Member States and exposing the trade of these resources to cross-border competition [30]. The underlying idea of the electricity market design is that a competitive single market, where electricity prices are formed based on supply and demand, will be able to achieve the EU's energy policy objectives, including security of supply, in the most cost-efficient way. The higher the demand, the higher prices rise. High prices signal scarcity and allow electricity producers to increase their profitability, which is expected to lead to new investment being made in the most cost-efficient way [31]. For the market structure to work, prices must be allowed to rise to a level that signals scarcity [32]. This is the fundamental assumption underpinning the legislative framework in the EU and the context in which the drastic price variation should be examined.

In light of this market design, it is the market forces rather than the states or regulator that should be guiding price formation and new investment in the electricity sector [32]. The market-based approach in EU law is not only evident in the electricity market design, but also in the design of the EU Emissions Trading Scheme, which is another market-based instrument that affects the price of electricity. Allowing market-based price formation is typically not a political issue when prices are low or average, or when there are no resource adequacy concerns in the near future. However, high or extremely high electricity prices are a politically sensitive matter, and therefore often entice regulatory interventions that prevent prices from rising, or otherwise distort the functioning of energy-only markets [33]. One example of such regulatory interventions is capping wholesale electricity prices to keep them affordable for consumers and industries. Although this is a politically appealing solution in the short-term, it may prevent prices from rising to a level that would signal scarcity in the long-term and undermines the underlying assumption on which the entire EU electricity market is designed. Capacity mechanisms provide another illustrative example of State intervention that aims to ensure sufficient resource adequacy in the electricity sector by compensating electricity producers for the availability and readiness of generation resources to supply electricity. Similarly to price capping, capacity mechanisms have been identified to have potentially distortive effects on the functioning of the internal energy-only market, and are controlled by EU law [34].

With this background, the Clean Energy for All Europeans package, which came into force in 2018 and 2019, introduced new rules that aimed to further enforce the functioning of the energy-only market in the EU. Within the package, the relevant electricity market rules are enshrined in the Electricity Regulation and the Electricity Directive.

The Electricity Regulation prohibits both maximum and minimum limits to wholesale electricity prices (Article 10 of the Electricity Regulation). Maximum and minimum limits on clearing prices may only be set by the nominated electricity market operators if the following conditions are met: the limits must be sufficiently high so as not to unnecessarily restrict trade, they must be harmonised for the internal market, and they must take the maximum value of lost load into account, which refers to an estimation of the maximum electricity price that customers are willing to pay to avoid an outage (Articles 2 and 10 of the Electricity Regulation). In other words, capping wholesale electricity prices is not allowed in principle, although maximum and minimum clearing prices can be, and have been, set (Article 41 of Commission Regulation (EU) 2015/1222 of 24 July 2015, establishing a guideline on capacity allocation and congestion management, OJ L 197, 25.7.2015, p. 24–72).

The Electricity Regulation also establishes principles regarding the operation of electricity markets (Article 3 of the Electricity Regulation). In addition to Member States themselves, regulatory authorities, transmission and distribution system operators, market operators, and delegated operators are all obligated to ensure that electricity markets are operated in accordance with these principles. In the context of the high electricity prices in Europe, several of these principles are relevant and highlight the expectations based on which the electricity markets are expected to operate. First, prices must be formed based on supply and demand. Secondly, market rules should facilitate the development of more flexible generation, sustainable low carbon generation, and more flexible demand. Demand response has been recognised as an important element to improve the flexibility of the electricity system since a decade ago (Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315, 14.11.2012, p. 1–56). Third, market rules must deliver appropriate investment incentives for generation, in particular, for long-term investments in a decarbonised and sustainable electricity system, energy storage, energy efficiency, and demand response to meet market needs. The rules must "facilitate fair competition thus ensuring security of supply", which underlines the expectation that fair competition is, indeed, an instrument to ensure or at least positively contribute to security of supply and affordability as an element of security of supply. Fourth, barriers to cross-border electricity flows between bidding zones or Member States and cross-border transactions on electricity markets and related service markets should be progressively removed. Finally, long-term hedging products should be tradeable in order to allow market participants to be protected against price volatility risks on a market basis and mitigate uncertainty on future returns on investment.

All these rules underscore the primacy of market-based rather than state-driven approaches to price formation in the electricity sector. Even though the market-driven approach is expected to ensure energy supply at the lowest cost to the consumer in the long-term, it inevitably also means high prices at times, and consequently, critical concerns over affordability and energy poverty insofar as the high prices are reflected in the retail electricity markets. Nevertheless, consumers are encouraged to enter into dynamic price contracts, which mean supply contracts that reflect the price variation in the spot markets (Articles 2 and 11 of the Electricity Directive). This is expected to allow consumers to adjust their consumption according to real-time price signals. In fact, Member States should ensure the reasonable exposure of consumers to wholesale price risk (Recital 37 of the Electricity Directive).

At the same time, ensuring the affordability of electricity in a power-dependent society is a key objective in the regulatory agenda of most European states and reflected in the legal framework on the EU level. The Electricity Directive addresses this objective with rules on basic consumer contractual rights, vulnerable consumers, and energy poverty (Article 5 and Chapter III of the Electricity Directive). These rules give Member States a broad margin of discretion in defining what constitutes a vulnerable consumer or an energy poor consumer.

Member States are obliged to protect energy poor and vulnerable household customers, but that protection must be ensured through social policy or "by other means than public interventions in the price setting for the supply of electricity" (Article 5 of the Electricity Directive). Price setting to protect energy poor or vulnerable household customers is only permitted if certain conditions are met. Namely, the interventions must be proportional, clearly defined, transparent, non-discriminatory, and limited in time and they must not result in additional costs for market participants in a discriminatory way. There is also a transition period during which similar interventions may be imposed to protect other household customers and microenterprises (Article 5 of the Electricity Directive). As a response to the high prices in 2021, the European Commission published a 'toolbox' of measures Member States could use to address the negative impact of high energy prices on households and businesses [35]. In 2022, the Commission published the REPowerEU initiative, the purpose of which was to reach independence from Russian fossil fuel supply and address high energy prices [10].

These rules demonstrate that ensuring affordability of electricity supply is an objective protected within the EU regulatory framework and that instruments exist to protect vulnerable and poor energy consumers. However, the rules also underline the primacy of the market-based approach to price formation and highlight the fact that affordability can seem somewhat subordinate to achieving a truly integrated and competitive internal market in electricity. It is in this context that the drastic price increases in 2021 are next analysed.

3. The Development of European Power Prices in 2021

To understand Finnish electricity price formation, an understanding of Central European electricity price development is first needed. Germany, in particular, significantly impacts the Nordic power markets via direct trade between Norway, Sweden, and Denmark, and indirectly via setting an opportunity cost for Nordic producers with significant hydro reservoirs. The German power market is larger than the Nordics combined, and hence, impacts the price formation of the entire region. Furthermore, German power prices are directly linked to thermal generation costs.

The year 2020 witnessed record-low energy prices throughout Europe, and many bidding zones experienced negative wholesale power prices for the first time. The following year, 2021, was the polar opposite of 2020, as both European commodity and power prices soared to new highs towards the end of the year. This was the result of multiple compounding and partly interrelated phenomena, which will be explored further in this article.

Electricity demand increased along with the European economic recovery in 2021, resulting in higher demand for coal, gas, and CO_2 emission allowances. Moreover, the demand for gas increased due to the cold weather in Europe during the winter and early spring. April 2021, when European gas storages are typically filled, was exceptionally cold [36], which resulted in low storage levels toward the start of the new gas year, which begins in October. The hot summer increased the demand for power due to a higher need for air conditioning, and concurrently, the high demand for electricity due to a hot summer in Asia decreased the availability of liquefied natural gas (LNG) supply in Europe [37]. In addition, gas supply from Russia was still notably below the pre-2020 levels [38]. The combination of these events reverted the trend of gas being more competitive than hard coal in power production.

Temperature was not the only weather-related phenomenon in 2021 that increased electricity prices; after an exceptionally wet, windy, and sunny 2020, the year 2021 was dry, windless, and cloudy. Southern Norway, which has a growing role in supplying cheap and flexible hydropower to Central Europe, the UK [39], and the rest of the Nordics, suffered of droughts, and German wind and solar production increased little from 2020, despite the notable increase in generation capacity [1,40].

The increased European climate ambition, coal resuming to be the source of baseload power, and the escalated demand for energy significantly hiked up the European emission allowance price, from 33 EUR/t at the beginning of the year to over 90 EUR/t in December 2021 (Figure 1). However, the drastic emissions allowance price increase was overshadowed by the increase in gas prices in Europe; Figure 1 depicts the development of commodity prices in Europe in absolute values and indexed terms. Title Transfer Facility (TTF) and Argus/McCloskey API2 gas and coal prices were considered in this article, respectively, as they are the most representative products in Europe. Data in the figure is obtained from [23–25].

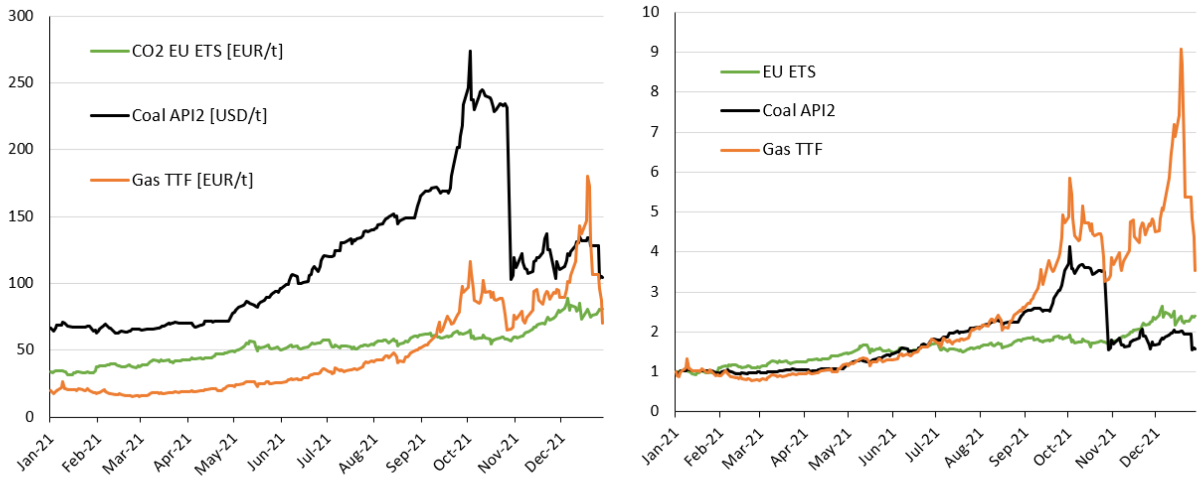

Figure 1. Development of commodity prices in Europe in absolute values (**left**) and indexed terms (**right**).

The price development of coal, gas, and emissions allowances is relevant because power price in most of the large European power markets follows the short-run marginal costs (SRMC) of thermal production, particularly the SRMC of gas lately. To illustrate this correlation, Figure 2 presents the daily German day-ahead price [1] against the SRMCs of gas and coal with the set of parameters presented in Table 1 [26]. The SRMC of coal has been so much below the SRMC of gas that coal-fuelled generators have been in baseload, whereas gas-fuelled plants have been the marginal producers, thus setting the power price in countries such as Germany.

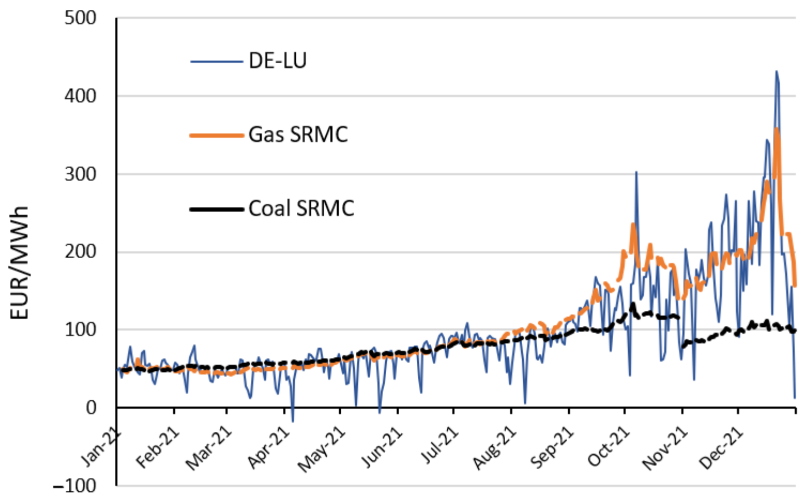

Figure 2. Daily short-run marginal costs (SRMC) of gas and coal and German day-ahead electricity price.

Table 1. Parameters used for calculating the short-run marginal costs of coal and gas.

	Gas	Coal	
Efficiency	55	43	%
CO_2 intensity	0.18404	0.34056	t/MWh
VO&M	2.5	4	EUR/MW
Energy content	-	7	MWh/t

The SRMCs for day *t* are calculated as follows:

$$(\text{Fuel price}_t + CO_2 \text{ intensity} * CO_2 \text{ price}_t)/\text{Efficiency} + \text{VO\&M cost}$$

The applied SRMC parameters represent a modern condensing coal plant and an average combined cycle gas turbine (CCGT) plant. However, there is significant spread in the SRMCs of different plants within the technologies, particularly in those fuelled by gas. As can be seen from the graph, the average German daily power price fluctuated around the SRMC of gas, particularly in the last quarter of the year. In other words, the production costs of gas have been setting the power price. This correlation has consequences for the power price formation and market dynamics during the price peaks of 2021 in Finland, which is the focus of the next subsection.

3.1. Power Price in Finland

Finland has typically enjoyed low electricity prices due to its Nordic neighbours, despite not having as prominent wind and hydro resources as Norway and northern Sweden. Finland's connections (marked with black arrows) to its neighbouring markets are presented in Figure 3 (map modified from [1]). As of May 2022, however, electricity trade between Finland and Russia has stopped, as RAO Nordic announced the termination of electricity exports to Finland [41]. Low electricity prices have been crucial in terms of affordability, as a notable share of domestic heating in Finland is based on electricity, and approximately one tenth of Finnish consumers have direct exposure to hourly spot market prices through their electricity contracts [42]. The most common residential consumer tariffs are either fixed price for a fixed-term or fixed price contracts that are valid until further notice.

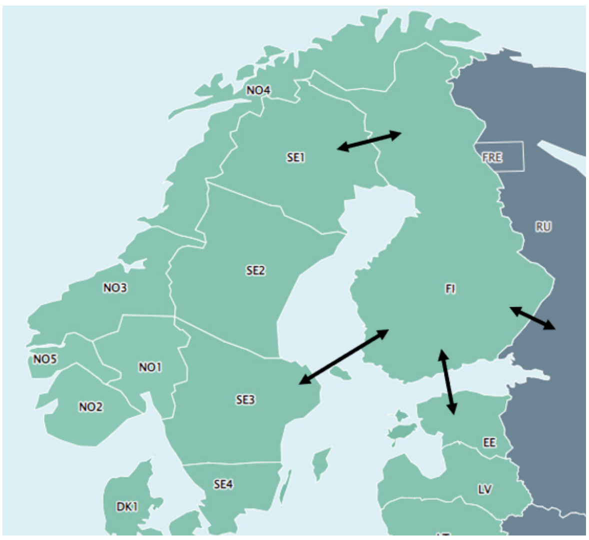

Figure 3. Finland and its connections to its neighbouring market areas.

The temperature, especially in northern Finland, can drop very low, and the highest spot prices tend to take place during cold spells. Moreover, Finland's economy relies significantly on energy-intensive industries whose competitiveness can be very sensitive to the price of electricity. Thus, the soaring electricity prices were a heated topic in Finnish media and political discourse in late 2021, culminating in a price peak of over 1000 EUR/MWh in 7 December [1]. It should be noted that average prices impact affordability more than single price peaks, but notable peaks make the headlines.

Finland has a diversified production mix, comprising large shares of nuclear, hydro, wind, and thermal combined heat and power (CHP) production. In 2021, the shares in total electricity generation were the following: nuclear 33%, hydropower 23%, biomass 20%, wind power 12%, natural gas 5%, and coal 5% [27]. Most of the production has either very low marginal costs, e.g., nuclear, wind, and hydro, or is mainly operated according to the demand for heat, e.g., industrial or district heating CHP. Therefore, the hourly price in Finland is often set by Finland's neighbours through market coupling. The highest price peaks often originate in Estonia, which was also the case in December 2021. During high prices, Finland typically decouples from Sweden (both SE1 in north and SE3 in south), couples with Estonia, and exports power to Estonia. As can be seen from Figure 4 [1], the daily Finnish day-ahead price typically resides between that of SE1, which comprises practically only hydro and wind, and Estonia, where the main source of electricity are oil shale plants built over 50 years ago [43]. The next subsection will focus on the price peaks on 7 December 2021 to demonstrate the consequences of these market dynamics.

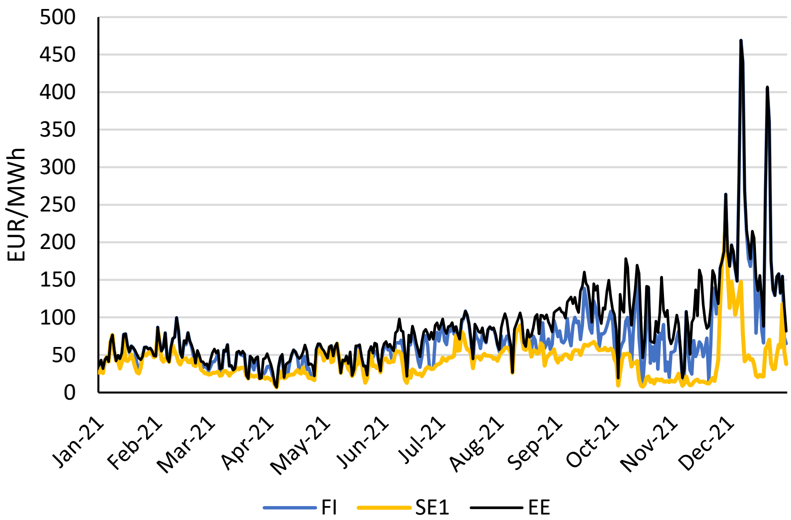

Figure 4. Daily spot prices in Finland, Estonia, and SE1 in 2021.

Finnish Price Peak on 7 December 2021

On the Tuesday of December 7, 2021, Finland witnessed a price peak of 1000.07 EUR/MWh at 7–8 a.m. Central European Time. This was the highest spot price in Finland in more than a decade, and Finland coupled with the Baltic countries, Estonia, Latvia, and Lithuania, throughout the day. Figure 5 presents the hourly spot prices in Finland and its neighbours on December 6–12 [1]. The weather was exceptionally cold for early December, and prices of CO_2 emission allowances and gas were at their all-time high, as demonstrated by Figure 1. However, power demand in Finland during the price peak was only approximately 13.5 GW (comparing to over 15 GW during the all-time high in early 2016) [21,44], and there was nothing unusual in the fundamental power system behaviour at the time; all nuclear plants were running with full capacity, wind production was close to its annual average, hydro availability was reasonable, and the availability of imports from Sweden and Russia was abundant. Furthermore, the availability of thermal power in Finland in early December was much higher in 2021 than in the three preceding years, which was mainly due to the cold weather allowing more CHP power production. Thus, the explanation for the high prices does not originate in the Finnish power system.

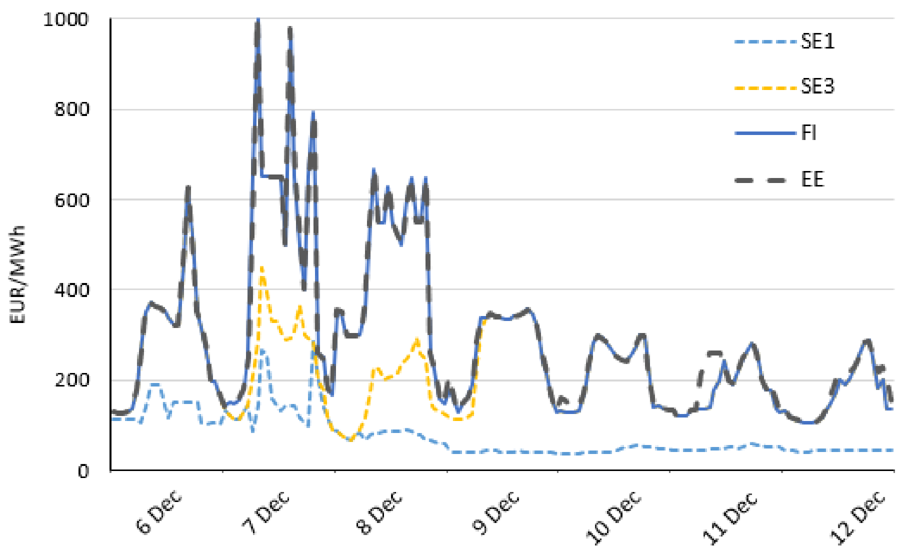

Figure 5. Hourly day-ahead prices between 6–12 December in Finland, Estonia, SE1, and SE3.

During the price peaks, Estonia was importing both from Finland and Latvia, as seen from Figure 6, thus setting the power price on that hour. The dotted lines in Figure 6 represent the available day-ahead capacities for the interconnectors between the relevant bidding zones (SE1–FI, SE3–FI, FI–EE, and LV–EE) and the blue line shows the scheduled commercial flows [1,21]. As the capacities of FI–EE and LV–EE interconnectors were not congested, the markets did not decouple during the peak. In practice, when the blue line touches the dotted line, the markets decouple. Finland was also importing from Russia, but as it is not a part of the internal electricity market in Europe, it does not directly impact price formation in the market [22].

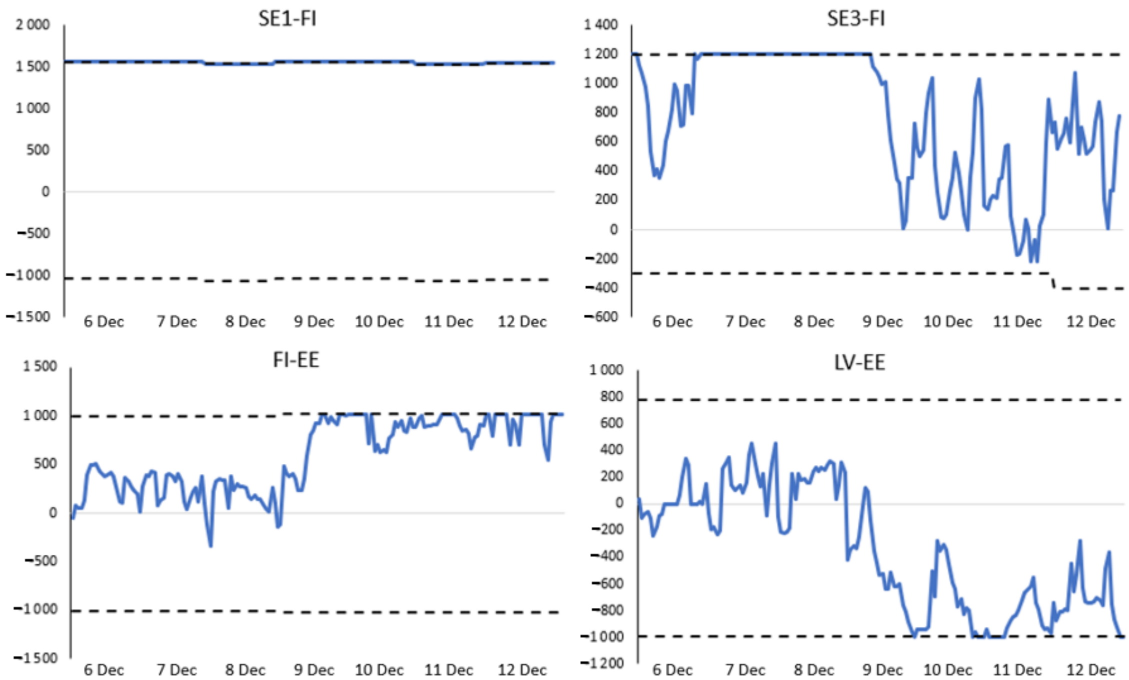

Figure 6. Hourly scheduled commercial flows for Finland and Estonia during 6–12 December.

To understand the general supply–demand balance in the Nordics, Figure 7 presents the supply and demand curves for the system price, which is an unconstrained market clearing reference to indicate the price level in the Nordic region. In practice, it is calculated by assuming that there is no network congestion within the Nordic market (Norway, Sweden, Finland, and Denmark), and is mainly used as a reference price in the financial markets. However, it gives an estimation on the elasticity of Nordic supply and demand. The system price during the highest price peak was 266.02 EUR/MWh [1], which is notably below the realised Finnish area price. As can be seen from the slope of the non-increasing curve in Figure 7 [1], the demand is highly inelastic compared with supply. The spread in supply bid prices, on the other hand, is seemingly narrow, between 22 and 54 GW, after which the price skyrockets as the system runs out of available capacity. This explains why prices increase so rapidly when approaching scarcity.

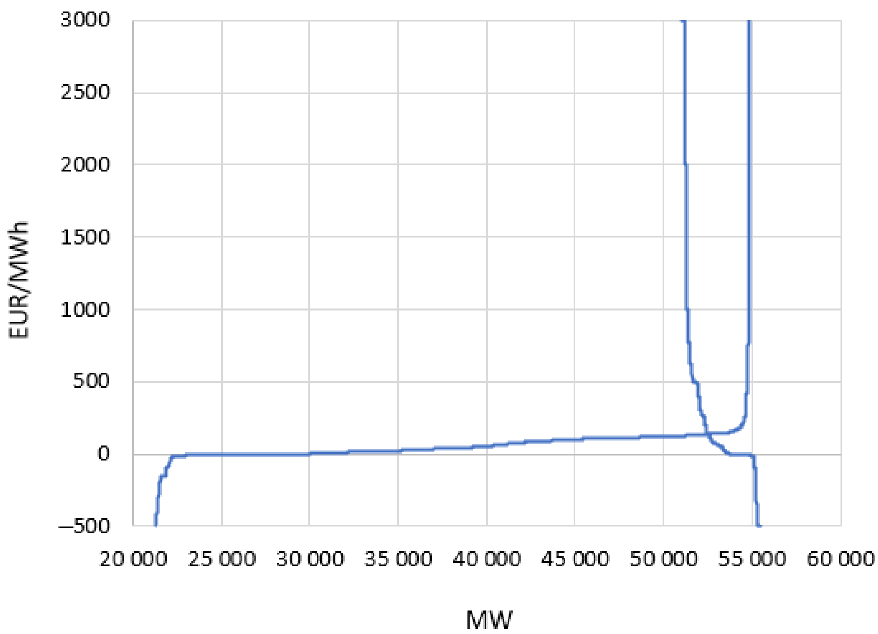

Figure 7. Nordic system supply and bid curves from hour 7 on 7 December 2021.

Figure 8 presents the actual Estonian oil shale production between 4–9 December plotted against the corresponding hourly day-ahead electricity prices [1,21]. As Estonia was largely setting the power price during that period, and oil shale comprises the vast majority of Estonian power production, the plotted black curve gives a rough indication of the Estonian supply curve at that time. The actual production may not perfectly correspond with day-ahead supply bids, as the production may comprise unexpected outages or start-ups of units for the intraday markets. Nonetheless, the graph indicates that, after a certain threshold, the coupled bidding area simply runs out of available capacity and demand-side flexibility. The plotted graph indicates that as little as 50 MW additional capacity or demand-side flexibility could have resulted in a day-ahead price between 100–200 EUR/MWh.

In the Nordic intraday market (Elbas), the flows from Finland to Estonia were 373 MW during the price peak. As interconnectors between Finland and Sweden were already congested, net Elbas sales in Finland were correspondingly 373 MW. Elbas flow from Estonia to Latvia was 287 MW during the peak. Balancing markets during the highest peak did not indicate any lack of available capacity, and only downregulation bids (either decreased production or increased consumption) realised in Finland during the morning peak. Moreover, there would have been over 1300 MW of upregulation bids (either increased production or decreased consumption) available in the balancing market during the morning peak hour [1], i.e., there was plenty of margin in the system left.

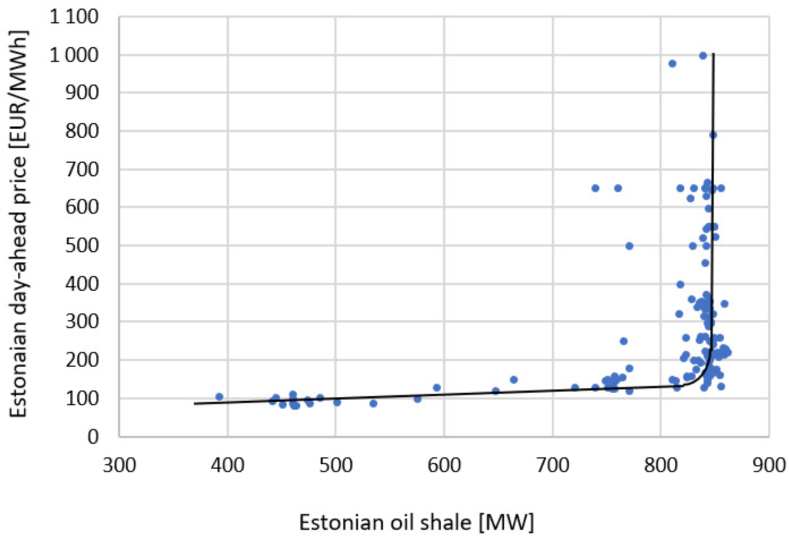

Figure 8. Estonian hourly oil share production against the realised day-ahead market prices for the corresponding hours between 4–9 December 2021.

4. Are the High Prices Here to Stay?

Many European households and industries are keen to know how electricity prices develop, particularly with all the uncertainty related to energy imports from Russia. However, forecasting prices in electricity markets is incredibly difficult, as the past two years have shown; the forward markets did not predict the price collapse of 2020, let alone the subsequent elevated prices of 2021. This section aims to assess some of the most relevant fundamental changes in the markets to come by winter 2022–2023. As the developments in Continental Europe, particularly in the German power market, impact Nordic prices both directly, through market coupling via Denmark and southern Sweden, and indirectly, by setting the opportunity cost for hydro producers in southern Norway, it is essential to include the German market outlook to understand the Nordic, and hence, the Finnish price development.

4.1. Fundamental Market Development

There are multiple ongoing fundamental changes in the European electricity markets that either support the prices (bullish factors) or weigh them down (bearish factors). In order to properly assess the aggregated impact of all the factors, sophisticated power system modelling with suitable uncertainty and scenario analyses is required. This kind of a comprehensive approach is beyond the scope of this article; we will instead identify and explore some of the key bullish and bearish factors and provides a qualitative view on their impacts.

On the one hand, notable bullish factors in Europe (in addition to the uncertainty related to Russian energy imports) are, inter alia, the phasing out of a significant amount of coal and nuclear capacity, electrification of transportation and industrial sectors, and accelerating climate ambition, which results in higher emission allowance prices. Nuclear power has very low short-run marginal costs, and hence, a decrease in nuclear capacity is clearly a bullish factor. Despite the inefficiency and high emissions, the market participation of old coal plants also has a bearish impact on electricity prices, particularly now that the price of natural gas is so high. However, uncertainty around the availability of natural gas in Europe has spurred discussion about delaying the coal phase-out in countries such as Germany and Belgium [45]. Higher electricity demand through electrification will push the point of intersection between supply and demand further, resulting in higher prices.

If the ambitious EU plans for hydrogen economy materialise, demand for electricity will increase further [46]. If the demand for electricity increases faster than the availability of low-cost, low-emission sources of electricity, such as wind, solar and nuclear, this will result in a higher demand for coal and gas, which will eventually support the price. Higher CO_2 prices through climate ambition directly increase the SRMCs of both gas and coal, which will impact the prices for as long as there remains a sufficient gas or coal capacity in Europe.

Notable bearish factors, on the other hand, are, inter alia, the prominent increase in European wind (both onshore and offshore [47]) and solar capacities, and regression toward the mean in many of the extreme events of 2021; climate models do indicate increased uncertainty and more severe extremes [48], but the droughts in hydro-dominated regions are likely to pass [49], winters are likely to be milder than the ones in early and late 2021 [48], and wind and solar conditions are likely to improve after a cloudy and windless year. However, forecasting the weather in the long-term may be even more difficult than forecasting electricity prices. It is plausible that extremes will be followed by even stronger extremes.

The most notable fundamental market developments for Finland are the planned deployment of Olkiluoto 3 (OL3), a nuclear power plant with 1600 MW capacity, and the rapidly increasing wind power capacity. OL3 has already started generating electricity, and it is planned to come fully online in late 2022 [50,51]. Deployment of OL3 should more than offset the cessation of electricity imports from Russia to Finland. The commissioning schedule of OL3 has been notoriously delayed, as the original schedule for deployment was in 2009. Finnish wind power capacity is currently increasing rapidly and is estimated to continue doing so for years to come; it was at 3257 MW by the end of 2021, and the projects currently under construction will more than double the capacity by the end of 2024 [52]. The new nuclear and wind generation will likely reduce net electricity imports from Sweden, as well as coal-fired generation, as many of Finland's remaining coal power plants are to be decommissioned in 2024 [53], and the rest by 2029.

As the Finnish electricity price is influenced by Estonian developments, Estonian fundamental developments also play a role in the assessment of the Finnish electricity market. The Estonian company operating the country's oil shale power plants, Eesti Energia, has set a target of abandoning oil shale in electricity production during 2026–2030 [54]. The impact of this decision on power prices will be determined by what replaces the oil shale production and what happens to Estonia's import/export balance during the transition period. Also, the Baltic grid development will play a role in the Finnish power price formation in the near future. First, the Baltic region will desynchronise with the Russian energy system and join the Continental European power grid and frequency area by the end of 2025 [55]. Also, the Baltic countries jointly agreed in 2020 to stop electricity imports from Belarus in protest of the Belarus nuclear power plant, Astravyets. In December 2021, negotiations on increasing imports from Russia and Belarus were again initiated [56,57], but they were reverted again in March 2022. Additional electricity imports from a market outside the European Emission Trading System would likely improve the supply/demand balance, and hence, decrease electricity prices; however, it seems likely that electricity imports from Belarus and Russia will be small or zero as long as the war in Ukraine continues.

4.2. Financial Market Outlook

One indication of market participant consensus on electricity price development can be deducted from financial markets. Electricity and commodity futures are traded for different periods, such as calendar years, quarters, months, and weeks. Figure 9 presents the historical monthly day-ahead prices in Finland, the Nordics (system price), and Germany in 2020–2021 [1], and forward curves for the corresponding markets [29,58]. Despite the lack of a direct connection between Finland and Germany, there has been a historical correlation between the prices. The forward prices are the closing prices from 26 August 2022 and are built using monthly prices as long as they are available, then quarterly, and then annual. The Finnish forward price is calculated as the sum of the Nordic system price and the Finnish electricity price area differential (EPAD).

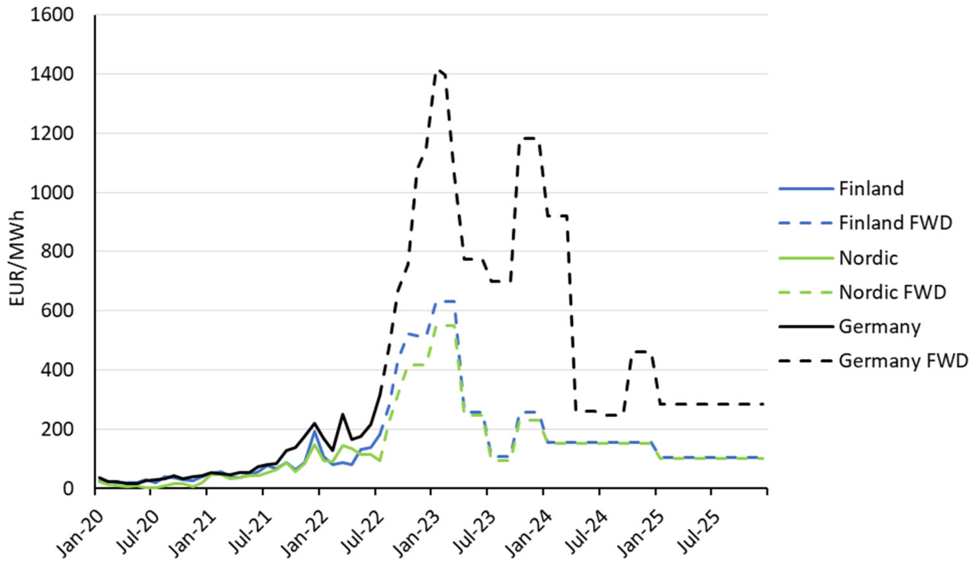

Figure 9. Historical monthly day-ahead prices in Finland, Nordics, and Germany, and forward curves (FWD) from 26 August 2022.

A couple of conclusions can be drawn from the graph. First, as of 26 August 2022, the average power price in Finland is expected to be almost three times as high in winter 2022–2023 than what it was in late 2021. Moreover, the Baltic states witnessed a day-ahead power price peak of 4000 EUR/MWh already on 17 August 2022, suggesting unforeseen volatility in the coming winter. Second, the markets expect that there will only be a relatively small premium in the Finnish price over the Nordic system price. Third, the historical correlation between German and Nordic prices is expected to break, and German prices are expected to be up to three times higher than in the Nordic countries this coming winter.

It should be noted that the forward prices do not necessary reflect the best guess or the market consensus on the exact expected price realisations, due to different hedging strategies or lack of liquidity. Some producers may sell electricity at relatively low prices in the financial markets just to be prepared for an unlikely bearish scenario, such as the one that took place in 2020, and some power consumers may be willing to pay a premium to be able to avoid an unlikely bullish scenario, such as that experienced in 2021 or 2022. The lack of liquidity can be a problem for smaller market areas, where there simply are not enough market participants to have the needed counterparties for transactions to materialise. This has also been the case for residential consumers, as retail companies have grown less keen to guarantee (low) fixed prices after the wave of retail company bankruptcies in Europe in 2021. It should also be noted that the forward curves presented in this article are just a snapshot from one trading day, as the prices are constantly changing. Any fundamental market change, e.g., restrictions on natural gas imports from Russia, a change in German coal phase-out schedule, or even a change in long-term weather forecasts, will impact market participant views on price development, and thus, the forward curves.

4.3. Discussion on Price Exposure

It seems intuitive that electricity producers would recover high income during the price peaks whereas electricity users, both residential and industrial, would face severe adverse economic consequences as a result of the price peaks. However, identifying the winners and losers during a price peak is not that straightforward. For example, in August 2021, two European utilities, Fortum and Uniper, reported hedging levels of 75 and 90% with average prices of 33 EUR/MWh and 26 EUR/MWh, respectively, for their Nordic generation for the remainder of the year [59]. Thus, the average electricity sale prices received by the companies during that period were far from the realised day-ahead price levels. Also, most residential electricity consumers still have fixed-price contracts, and the energy-intensive industry typically hedges their electricity consumption. Therefore, most electricity consumers have also survived the price peaks unscathed. The most financial damage has hence been experienced by those with too much exposure to high electricity prices, either through a spot market-based electricity contract (residential consumer) or via the lack of hedging (industrial consumer).

The above situation has interesting implications for the market-based legal and regulatory framework presented in Section 2. The internal market design for electricity assumes that prices occasionally rise to a level that signals scarcity, which allows power producers to increase their profitability and incentivise new investment. If power producer profitability does not increase during these high prices, the incentivising effect is lost, at least in the short-term, and the market does not deliver appropriate investment incentives for generation, as required by the Electricity Regulation. In the long-term, this is assumed to lead to less cost-efficient prices for both residential and industrial customers. Furthermore, consumers with fixed contracts are not given sufficient incentives to moderate their demand during scarcity hours, thus increasing the flexibility of the power system.

At the same time, the affordability dimensions of the high prices cannot be disregarded. The economic impact of the price peaks on customers that have not hedged their risks has been palpable. Nevertheless, the EU legal framework has a reluctant approach to regulatory intervention where governments support electricity users during high prices by means of public interventions in the price setting. This is especially the case for those customers who have deliberately chosen more exposure to price volatility, when there has also been an option for fixed prices via electricity contracts and financial markets. However, it seems that the EU is likely to adopt new legal instruments to address high prices, especially through the REPowerEU initiative. Furthermore, it should be noted that many lack the option to hedge their prices, as retailers in Finland have grown less keen to guarantee (low) fixed price levels, and smaller market areas often lack the needed liquidity in the financial markets. Nevertheless, rather than relying on State-driven interventions to address issues of affordability for these customers, the market design is underlined by the need to develop *market-based* hedging instruments and managing the risks associated with exposure to wholesale price variation.

5. Conclusions

This article set out to explain and explore the causes of the radical electricity price increases in Northern Europe in 2021 using Finland as an illustrative case study. Moreover, the article assessed likely future price developments of winter 2022–2023, after the Russian invasion of Ukraine. To achieve this, the article first explained the European market and regulatory design to demonstrate the preconditions within which the market is expected to function. This analysis showed that although affordability as an element of energy security is a key objective in the regulatory framework, the European electricity market design also fundamentally necessitates price variation to ensure market-based investment and energy security in the long-term.

The article then explored how the legal and regulatory preconditions functioned in practice in late 2021. It analysed the complex dynamics of electricity price formation within the European energy market using Finland as a case example. Power prices climbed in Finland throughout 2021, culminating in a wholesale price peak of over 1000 EUR/MWh in early December. Remarkably, the analysis demonstrated that the Finnish power system was functioning completely normally during the peak and there were no indications of generation inadequacy. In other words, power demand during the peak was far from an all-time high, and generation capacity, as well as interconnections to neighbouring markets were available. Also, there were no signs of scarcity in intraday or balancing markets. That is to say that though import dependence is often highlighted as the likely culprit of energy security issues, this was not the case in Finland in 2021. In fact, the analysis demonstrates that the origin of price spikes, and the resulting concerns over affordability, stemmed from exports to a neighbouring country.

The analysis demonstrated that the high prices originated in Estonia, and this too, is a feature of the European energy market design; Member States are not isolated but expected to rely on cross-border trade to ensure energy security. The impact of this approach to price formation in neighbouring Member States is hence unavoidable. This article showed that due to the shape of the supply curves presented in Figures 7 and 8, as little as 50 MW of additional demand-side flexibility or available generation or transmission capacity in the region could have resulted in 80–90% lower day-ahead prices than the studied price peaks. However, due to the complexity of price formation in European electricity markets, in reality, it would not have been a ceteris paribus situation, and a small change in supply or demand could have changed the dynamics in price coupling within the region as well.

Finally, the article assessed the likely future development of power prices via the foreseen fundamental changes caused by the uncertainties related to Russian energy imports. Despite Finland historically importing a notable share of its primary energy from Russia, the Nordic countries are not as dependent on Russian natural gas supply as Central Europe. Thus, new nuclear and wind power investments in Finland should offset a majority of the uncertainty related to Russian energy supply. However, Central European power prices are more strongly linked with the price of natural gas, and hence the markets price in notable premium in e.g., German power prices for winter 2022–2023 over the Nordic power price.

Overall, the analysis showed that the high energy prices have been the result of various weather-related, economic, and political factors. Moreover, the stark contrast to the unusually low European energy prices in 2020 further amplified the perception of elevated prices in 2021. However, comparing with the power prices of late August in 2022, the electricity prices experienced in late 2021 seem quite reasonable in hindsight. The increase in energy prices in 2021 and 2022 (as well as the drop in 2020) has exposed vulnerabilities within the energy sector, and in the economy in general. As Europe now aims to reduce dependence on Russian energy imports, concerns over affordability are even more tangible for the coming winter. In the long run, the trend of electrification, combined with the increase in weather-dependent generation within the European energy market is likely to lead to even greater volatility and corresponding extreme price signals, unless flexibility and energy security in general are not considered. Flexibility has been advocated since more than a decade ago, at the EU level, and it would be achieved by more spot-based contracts. However, the high prices of 2021–2022 have made them quite unpopular due to affordability concerns. Our analysis suggests that increased flexibility in day-ahead demand will be a crucially important element in preventing extreme price peaks.

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